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ABSTRACT

Research has documented the relationship between attributions and metacognition in the areas of memory, visual discrimination, and reading. The present study extended this research into the domain of mathematical problem solving. Thirty ninth-grade students who attributed performance to strategy, effort, or unknown causes were videotaped and asked to verbalize their thoughts as they solved a nonroutine mathematical word problem. Although there were no differences in overall metacognitive involvement between the three attribution groups, there were differences in the key metacognitive component: exploration. Students who attributed performance to strategy were more likely to regulate their exploration than those who ascribed to effort or unknown causes, and were more likely to solve the problem than students from the effort group. Students who made dual attributions to strategy and effort were not as likely to regulate their exploration or solve the problem as students who made "pure" strategy attributions. The findings support the need to investigate students' perceptions of "effort" as causal to performance, and to compare the effects of strategy versus strategy-effort feedback. (Author)

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**Beyond Effort:
A Look at Strategy Attributions
in the Domain of Mathematical Problem Solving**

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Paper presented at the annual meeting
of the American Educational Research Association,
New York, 1996

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Running Head: BEYOND EFFORT

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Abstract

Research has documented the relationship between attributions and metacognition in the areas of memory, visual discrimination and reading. The present study extended this research into the domain of mathematical problem solving. Thirty ninth-grade students who attributed performance to strategy, effort, or unknown causes were videotaped and asked to verbalize their thoughts as they solved a nonroutine mathematical word problem. Although there were no differences in overall metacognitive involvement between the three attribution groups, there were differences in the key metacognitive component - exploration. Students who attributed performance to strategy were more likely to regulate their exploration than those who ascribed to effort or unknown causes, and were more likely to solve the problem than students from the effort group. Students who made dual attributions to strategy and effort were not as likely to regulate their exploration or solve the problem as students who made "pure" strategy attributions. The findings support the need to investigate students' perceptions of "effort" as causal to performance, and to compare the effects of strategy versus strategy-effort feedback.

Beyond Effort: A Look at Strategy Attributions in the Domain of Mathematical Problem Solving

In academic contexts, students often have opportunities for forming and expressing beliefs about the causes of their successes and failures. These causal beliefs, or attributions, have long been viewed as having both motivational and academic consequences (Weiner, 1979, 1985). Students who attribute performance to internal and controllable factors, such as their own efforts, are not only likely to persist in the face of failure but continue to actively monitor their learning process (Diener & Dweck, 1979). The relationship between attributions and metacognition has been documented for performance on visual discrimination and study tasks, and in the areas of memory and reading (e.g., Diener & Dweck, 1979; Borkowski, Carr, Rellinger, & Pressley, 1990; Borkowski, Weyhing, & Carr, 1988; Turner, Dofny, & Dutka, 1994). The purpose of the present study was to extend this research into the domain of mathematical problem solving.

During mathematical problem solving, students often do not get challenged enough to expect high levels of metacognitive monitoring (Kluwe, 1987; Reusser, 1988). They expect word problems to be solvable by step-by-step procedures that should take no more than twelve minutes to solve before being judged impossible (Schoenfeld, 1989). Students read the problem and then explore the solution with little time given to higher-level activities such as analyzing, planning or verifying (Schoenfeld, 1985). Without deliberate planning and analyzing of a problem,

students' exploration attempts may begin on a "hunch." The degree to which they monitor their "hunches," then, that is, evaluate when a path has led to a dead-end and regulate their efforts by selecting alternative paths, may be a crucial predictor of problem success. Among undergraduates solving nonroutine mathematical word problems, 42% of correct solutions were the result of switching strategies at an impasse (Koedinger & Tabachneck, 1994). Regulation is a metacognitive activity characteristic of more mature learners. That is, metacognitive research has demonstrated that ability differences in comprehension monitoring are not found for evaluation (keeping track of cognitive progress) but for regulation (fixing cognitive breakdown) (Jacobs & Paris, 1987; Zabrucky & Ratner, 1989). Furthermore, regulation may be related to attributional patterns (Fusco, 1994).

The specific purposes of this study were to examine whether metacognitive patterns, particularly regulatory efforts, were related to attributional beliefs, and to expand upon prior research by including attributions to strategy and unknown causes. While attribution research has predominantly focused on four causal factors (ability, effort, luck, and task difficulty), these are not the only factors students cite as causal to their performance (Weiner, 1985). As Rohrkemper (1986) points out, students' attributions, when measured "in action," that is, during problem solution, may differ than when assessed in relation to past performance or a hypothetical situation. Studies which use open-ended attribution measures and/or link causal

beliefs to actual task performance find that students often attribute performance to the use of strategies (Fabricius & Hagen, 1984). While strategy, like effort, is perceived as an internal, controllable factor, research supports separating the two or for expecting differences between strategy and effort attributions (Clifford, 1986; Hagen, Meyer, & Weinstein, 1994; Zimmerman & Martinez-Pons, 1986, 1992). For instance, self-regulated learners do NOT attribute performance to effort but rather to strategy use (Zimmerman & Martinez-Pons, 1992). Strategy attributions are positively related to persistence (Anderson & Jennings, 1980), cognitive strategy use (Fabricius & Hagen, 1984), self-regulatory capacities (Zimmerman & Martinez-Pons, 1986, 1992), and are likely to facilitate self-efficacy (Schunk, 1994). At times students are unable to locate a cause for their success or failure (Connell, 1985). These unknown control beliefs are negatively related to standardized achievement, teacher ratings of competency (Connell, 1985) and grades (Bethea, 1986).

In the present study it was hypothesized that students who recognized the causal role of strategies in their problem-solving performance would be more likely to regulate their explorations and verify their solution during mathematical problem solving, and be more likely to solve a nonroutine word problem, than those who attributed their performance to effort or unknown causes. Differences in analyzing, planning and implementing were not expected primarily because of the anticipated infrequency of such strategies (Schoenfeld, 1989). These activities were nonetheless

included for consistency with prior studies of problem-solving processes upon which this work borrows. The causal recognition of strategy, independently or in addition to effort, was expected to be more strongly related to metacognitive activities than effort alone. Finally, responses to open-ended attribution questions were expected to reveal a higher frequency of strategy, than effort, causation.

Method

Participants

The sample included 130 ninth-grade students from six math classrooms in one Catholic high school in New York City. All participants were girls and ranged in age from 13-16 (13 = 32%, 14 = 56%, 15 = 11%, 16 = 01%). Based on responses from the Attribution Questionnaire for Mathematical Problem Solving (AQ-MPS), thirty students were assigned to one of three attribution groups: Strategy, Effort, or Unknown. The ethnic breakdown for the thirty participants was: 40% Hispanic, 27% African-American, 10% Caucasian, 3% Asian, and 20% Other (i.e., West Indian, Brazilian, or of dual ethnicity). All students were native English-speakers.

Instruments

Attributions.

The AQ-MPS, designed for this study, was used to select students who attributed success and failure at solving mathematical word problems to strategy, effort, or unknown causes (Appendix A). Responses are based on a 5-point Likert scale (1, very true to 5, not at all true), thus low scores indicate

endorsement of the statement. There are six items for each of the Effort and Strategy scales (three worded for success and three for failure), and four items for the Unknown scale (two success and two failure). The alpha coefficients were: Effort = .60; Strategy = .53; and Unknown = .60. The questionnaire also includes two open-ended items (one worded for success, one for failure) which allowed for the difference between experimenter-defined and respondent-defined causation to be examined (see Vispoel & Austin, 1995). The Post-Task Attribution Questionnaire, an open-ended assessment, asked students if they solved the Banker problem (Yes/No) and "Why do you think you were or were not able to solve this problem?"

Mathematical word problems.

Two nonstandard mathematical word problems were used. The first was used as a practice task to familiarize students with the procedures, particularly the process of talking aloud during problem solving. The second, the Banker problem, was used to document metacognitive activities and problem-solving progress. The Banker problem states:

A banker must make change of one dollar using 50 coins. The banker must use at least one quarter, one dime, one nickel, and one penny. How many of each coin must the banker use to do this?

Metacognition.

Metacognitive activities were examined during problem solving based on think-aloud protocols and videotape recordings of students' work. The specific activities measured were Understanding, Analyzing, Exploring, Planning/Implementing, and

Verifying. The five activities were scored separately and combined (see Appendix B). The separate scores ranged from 0-5, and the total score ranged from 0-25. The scoring scheme was adapted and modified from prior research (Artzt & Armour-Thomas, 1992; Schoenfeld, 1985). Inter-rater reliability for the scoring was 89%; after discussion to resolve discrepancies, the raters met with 100% agreement.¹ Based on prior experience with students of similar age working on the Banker problem, it was expected that points awarded for necessary components could coincide with a problem solution. For instance, a student who receives 5 points in Understanding, 5 points in Metacognitive Exploration, and 5 points in Verifying is likely to have solved the problem. In fact, five points awarded for Exploration indicated that students regulated their explorations, that is, kept track of their solution attempts and built upon the results of their evaluations. Since Regulation was of particular interest, Exploration scores were also recoded (scores of 0 - 4 = 0; 5 = 1) to reflect a dichotomous distinction between students who regulated from those who did not.

Problem-solving progress.

Problem-solving performance was defined as an indication of progress with scores ranging from 1 to 5. The scoring scheme was adapted from Schoenfeld (1982). Scores were assigned as follows:

- 1 (little)- much guessing but no clear understanding of problem;
- 2 (some)- a reasonable amount but not enough to claim the

¹ Dr. Artzt provided her expertise as the second rater of metacognitive activities.

solution is almost in hand; 3 (almost)- something close to a solution; 4 (solved, with error)- correct solution marred by an incorrect calculation; 5 (solved)- correct solution.

Procedure

The AQ-MPS was group-administered by two female math teachers to all ninth-grade students ($N = 130$) at the beginning of the school year. Each student received three attribution scores, one for each category- Unknown, Effort, and Strategy. Ten students were selected for each of the three categories based on a maximum score of thirteen on only one scale and no "4" (not true) or "5" (not at all true) responses to any item. Five students selected for the Strategy category also had low Effort scores, that is, attributed performance to effort.

The thirty selected students were seen individually. Participants received the primer task in order to become familiar with the presence of the recorders, and the process of talking aloud. The camcorder was positioned on a tripod for a side view, capturing only the students' handwriting. Once the student was comfortable with the procedures, she was given twenty minutes to work on the Banker problem. During this time, the interviewer intervened only if a prompt to continue talking was necessary (see Taylor & Dionne, 1994). After twenty minutes, or when students correctly solved the problem, students completed the Post-Task Attribution Questionnaire.

Data Analysis

Students' responses to the open-ended attribution items on the AQ-MPS were analyzed separately for failure and success.

Statements which included more than one cause for performance were parsed and counted as separate statements. Statements were then grouped into categories based on the similarity of the responses. The percentages of responses in the strategy and effort categories were compared using a chi-square statistic, accounting for students who attributed performance to both strategy and effort. Attribution responses from the Post-Task Attribution Questionnaire were analyzed qualitatively.

To test hypotheses about group differences on metacognitive scores and problem-solving progress scores, attribution category (Strategy, Effort, or Unknown) was used as the independent variable in two one-way Analysis of Variance procedures, with total metacognitive score and problem-solving progress score as the dependent variables. A chi-square statistic was used to examine whether students from the Strategy group were more likely to regulate their problem-solving attempts. Finally, correlations were computed between separate metacognitive activity scores and problem-solving progress scores.

Results

Open-ended attribution responses

An analysis of the open-ended attribution responses from the AQ-MPS revealed twelve categories of causal reference (Table 1). For failure, effort ($n = 17$) was more frequently cited than strategy ($n = 13$) (chi-square = 15.29, $df = 1$, $p < .001$), though it was not the most frequent cause cited. Students believed that failure was most likely the result of not understanding the problem (20%). For success, students were more likely to ascribe

to strategy ($n = 29$) than effort ($n = 22$) (chi-square = 24.98, $df = 1$, $p < .001$), and strategy was the most frequent cause cited for success (20%).

Attribution responses ($N = 25$) from the post-task measure were categorized into four groups: External, Effort, Strategy, and Other (e.g., not understanding the problem). Five students were omitted since they responded as if they solved the problem when in fact they did not. Attributions to a problem-solving strategy were more likely to occur after success than after failure. Accounting for their success, students stated: 1) I started to do pictures and drawings; 2) I think what helped me solve this problem was making a chart; 3) I think that I was able to solve the problem because I followed directions; 4) I figured out a way to do it; 5) I try many different ways up til I solve the problem correctly. Of nineteen students who stated they did not solve the Banker problem, three attributed failure to a lack of strategy. Attributions following failure were typically more external, "Because I thought it was hard," or referred to a lack of understanding, "I wasn't able to because I didn't understand at first why you could only use one coin but it said at least one but I still didn't get it." Only one student attributed failure on the Banker problem to effort.

Attribution group differences

Results of an analysis of variance showed no significant differences between the three attribution groups, $F(2, 27) = 1.12$, $p = .34$, on total metacognitive score. The means and standard deviations were: Strategy, $M = 6.0$ ($sd = 4.6$); Effort, M

= 4.4 (sd = 2.1); Unknown, $M = 6.3$ (sd = 1.4). However, four students in the Strategy group received a score of five in Exploration (Regulated) while none of the students from either the Effort or Unknown group received this score, a significant difference ($\chi^2 = 15$, $df = 2$, $p < .001$). There was no significant difference in problem-solving progress among the three groups, $F(2,27) = 2.59$, $p = .09$. The means and standard deviations were: Strategy, $M = 2.7$ (sd = 1.6); Effort, $M = 1.5$ (sd = .71); Unknown, $M = 2.1$, (sd = .99).

Correlations revealed that Effort was significantly related to problem-solving progress ($r = .44$, $p = .007$), total metacognition ($r = .36$, $p = .03$), and Exploration ($r = .38$, $p = .02$). A positive correlation indicates that students who endorsed effort (low scale scores) had low outcome scores. Since five students in the Strategy group also ascribed to effort, differences between the Strategy-only and the Strategy-Effort students were explored. Though differences were not expected, an analysis of variance revealed a significant difference on problem-solving progress, $F(3,26) = 4.51$, $p = .01$ (see Table 2). A Tukey comparison indicated that the Strategy-only group had higher problem-solving scores than the Effort group. Interestingly, the four students who received an Exploration score of five were all from the Strategy-only subgroup.

Metacognitive activities and problem solving

There was a significant correlation between total metacognition and problem-solving progress scores, ($r = .68$, $p = .000$). Problem solving was also significantly related to

Exploration ($r = .73$, $p = .000$), Analysis ($r = .43$, $p = .008$) and Understanding ($r = .57$, $p = .001$). Unexpectedly, problem solving was not related to Verification ($r = .17$); 73% of the students did not verify.

Discussion

Students who attributed performance to unknown causes were hypothesized to have the least amount of awareness of the learning process. Being unable to locate a cause for one's success or failure seems to imply that the process of learning is acted out with little monitoring of the activities that brought one to the place of success or failure. Conversely, students who recognized the role of strategies in accounting for their performance, independently from or in addition to effort, were expected to monitor and regulate the strategies they used during problem solving and be more likely to solve the Banker problem than students who ascribed to effort. The predictions, though not supported, revealed some interesting inquiries.

There were no differences in overall metacognitive involvement between the three attribution groups and in fact, the Unknown group's metacognitive patterns were more similar to those of the Strategy group. Their "unknowing" did not hinder them from trying or from exploring possible paths. Interestingly, however, students from the Strategy-only group were more likely to regulate their exploration than students from the Effort or Unknown group and were more likely to solve the problem than the Effort group. That is, students who attributed success to

strategy and did not attribute success or failure to effort were more likely to regulate their exploration and solve the problem. While it is difficult to have confidence in this result since there were only five students in the Strategy-only group, these findings suggest some possible inquires for future research.

One prevailing notion is that effort attributions, because of their internal and controllable nature, are a positive indicator of motivational processes. However, self-worth theory postulates that students perceive high effort as implying low ability (Covington & Omelich, 1984). Self-regulation theory holds that effort is too vague a construct to provide any information about the "hows" of learning. While putting one's mind to it may be the impetus of learning, volition alone will not guarantee learning without the accompaniment of strategies. Attribution training research, for instance, indicates that stressing effort "in the form of attentiveness to the strategy" (Borkowski & Thorpe, 1994, p. 58), in addition to providing metacognitive strategy instruction, is likely to impact strategy use and performance. Future research would contribute greatly to this understanding by studying students' exact perceptions of effort as related to learning and attitudinal outcomes. Examining students' perceptions of effort in relation to the concrete enactment of "effort," i.e., whether efforts are deliberate and varying or reactive and redundant may also be useful. Finally, since "pure" strategy attributions, particularly for success, seemed most adaptive to this study's outcomes, the findings suggest the need to compare the effects of strategy and strategy-

effort feedback. Strategy attributions may be of a "meta" nature, that is, arising as an integral part of the metacognitive system. Future studies might examine at what point in the learning process students begin to account for their successes with strategies. Does success have to occur repeatedly with the same task? Does the onset of strategy attributions parallel the development of the metacognitive system? Are strategy attributions more prevalent in classrooms which are less concerned with academic outcomes than with learning processes?

Strategies used for problem solving

A total metacognitive score was not the best indicator of problem-solving success. Exploration, specifically the regulation of exploration, was the key aspect of this metacognitive process. Comparisons of good and poor readers indicate that poor readers are likely to evaluate their comprehension, e.g., notice a lack of comprehension, but are less likely to regulate, e.g., reread the text (Zabucky & Ratner, 1989). Similar differences in mathematical problem solving were found here.

While only four students solved the nonroutine problem within the allotted time, they all understood the problem's conditions and goal, and regulated their exploration, that is, evaluated their attempts and made new choices based on the results of the evaluations, e.g., "I only used 20 coins but have one dollar (evaluation), I better increase the pennies" (regulation). They did not necessarily analyze the problem, make a plan, or completely verify their solution (see Figure 1). Students who did not solve the problem either did not understand

the problem or understood the problem but were engaged in a largely cognitive problem-solving endeavor (see Figure 2).

While the results of this study cannot be generalized to the classroom, one can speculate that the level of metacognitive involvement students achieve in mathematics is stimulated by the classroom environment/approach. In Magdalene Lampert's (1990) classroom, students verbalize how they solve problems in a supportive group setting. The focus is not on right or wrong answers and analysis of errors is encouraged. Future research could examine classroom environments in relation to problem-solving processes and attitudes. In fact, strategy attributions for failure may only facilitate motivation in environments conducive to reflecting on errors without harming one's self-perceptions.

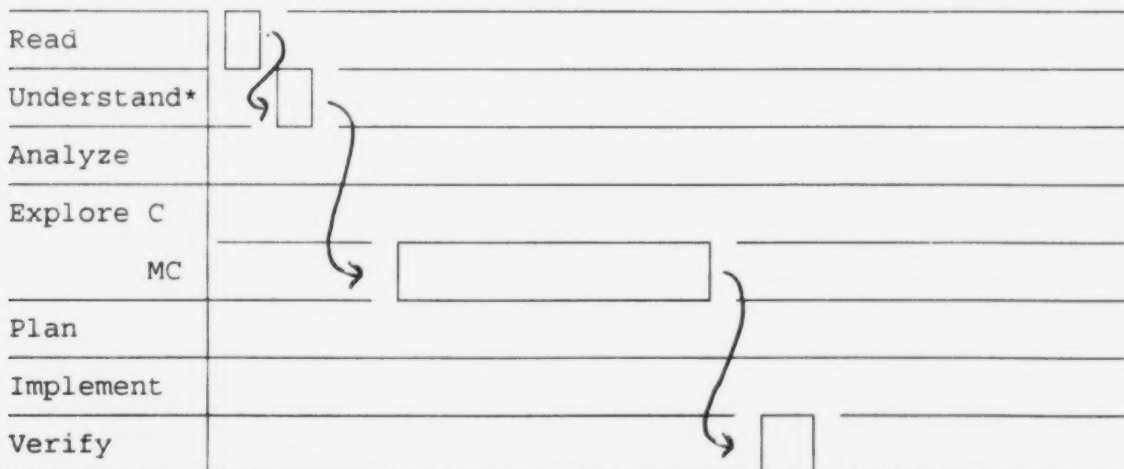


Figure 1. Metacognitive processes of a successful problem solver.
Note: C - cognitive, MC - metacognitive.

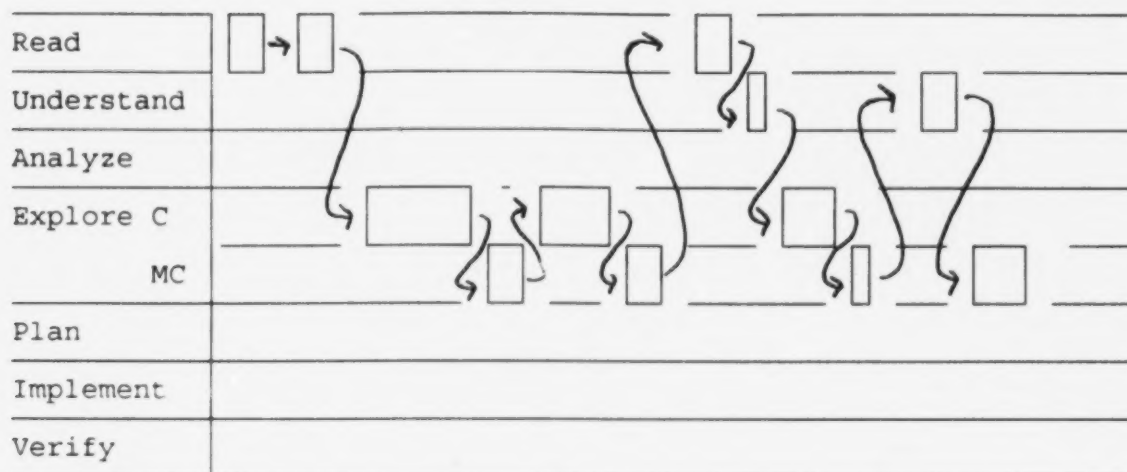


Figure 2. Metacognitive processes of an unsuccessful problem solver. Note: C - cognitive, MC - metacognitive.

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Table 1
Categories of Open-ended Attribution Responses

Sample Statement	Success	Failure
PROBLEM-SOLVING STRATEGY	34/.20	15/.09
Because I didn't follow the right procedure.		
COMPREHENSION OF PROCEDURE	30/.17	24/.14
Because I knew how to get the answer.		
ERROR	1/.01	9/.05
Maybe I missed a step.		
GENERAL STRATEGY	16/.09	13/.08
It happens because I don't pay attention in class.		
EFFORT	25/.14	18/.10
Sometimes it's because I don't try hard enough.		
COMPREHENSION	22/.13	34/.20
Because I understood the problem.		
STATE	12/.07	23/.13
Because I get tired quickly.		
AFFECT	12/.07	23/.13
Because it makes you feel good when you solve it.		
TASK	17/.10	10/.06
Because it's hard.		
OTHER	3/.02	2/.01
The teacher didn't explain it very good.		
ABILITY	1/.01	2/.01
I am good at solving problems.		
UNKNOWN	1/.01	0/.00
I don't know.		

Note: Frequencies are number of statements, not students.

Table 2

Means and Standard Deviations of Problem-Solving Activities

	Attribution Group			
	Unknown	Effort	Stra-Only	Stra-Eff
PS Progress	2.1 (1.24)	1.5 (.707)	3.6 (1.67)	1.8 (1.09)
TotalMeta	6.3 (1.41)	4.4 (2.11)	7.6 (4.72)	4.4 (4.39)
Understanding	2.1 (1.19)	2.0 (1.05)	1.6 (1.52)	1.8 (2.05)
Analyzing	.7 (.948)	.2 (.421)	1.2 (2.17)	.6 (.894)
Exploring	2.7 (1.49)	1.6 (1.50)	4.0 (2.24)	2.0 (1.87)
Verifying	.7 (1.25)	.3 (.483)	.8 (1.30)	.0 (.000)
Planning	.1 (.316)	.3 (.948)	.0 (.000)	.0 (.000)

Appendix A
Sample Items from the AQ-MPS

Category	Sample Item
Failure-Effort	If I did not solve a math word problem it was because I did not try hard enough.
Success-Effort	When I am able to solve a word problem it is because I really put my mind to it.
Failure-Strategy	If I cannot solve a word problem it's because I do not know a good way to solve it.
Success-Strategy	If I get a word problem right it's because I followed the steps I was shown.
Failure-Unknown	If I get a word problem wrong I usually do not know the reason why.
Success-Unknown	If I get a math word problem right it's hard to figure out the reason.
Open-ended items	When you <u>cannot</u> solve a word problem why do you think this happens? When you <u>can</u> solve a word problem why do you think this happens?

Appendix B

Scoring Scheme of Metacognitive Activities

Understanding (0-5 points): 1 point for each of 3 conditions; 2 points for recognizing the overall goal of the problem.

CONDITIONS:

1. A total of 50 coins must be used.
2. The value of the 50 coins must equal \$1.00.
3. At least one quarter, one dime, one nickel, and one penny must be used.

GOAL: *How many of each coin must the banker use to do this?*

Analyzing (0-5 points): Quality of analysis can be determined by considering the following questions: Which strategy is chosen? Is the choice made explicitly? Is the choice reasonable, driven by the conditions of the problem?

Planning/implementing (0-5 points)

1 point: Does the student show any evidence of being aware of his/her approach to the problem?

3 points: Does the student pursue the approach? (evidence plus pursuit)

5 points: Does the student monitor effectiveness of approach or does approach lead to a dead-end without the student's awareness? (evidence plus pursuit plus monitoring)

Exploration (0-5 points): 0 points for guessing without testing (cognitive only); 3 points for guessing and testing; 5 points for regulation, or making new guesses based on the results of the tests.

Verifying (0-5 points): Based on verification of the three conditions above. 1 point: verifies one stipulation; 3 points: verifies two stipulations; 5 points: verifies all three stipulations.